Materials Characterization Paper
In Support of the
Proposed Rulemaking –
Identification of Nonhazardous Secondary Materials That Are Solid Waste
Scrap Plastics

March 18, 2010

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1. Definition of Scrap Plastics

Scrap plastics under consideration here comprise three categories of material: scrap material from the manufacturing of plastic items, off-specification (off-spec) manufactured plastic goods, and packaging materials used in shipments to industrial users - typically plastic film, pallets, and "peanuts."

2. Annual Quantities of Scrap Plastics Generated and Used

(1) **Sectors that generate scrap plastics:**
Industrial scrap plastics are generated from the manufacturing of plastic products and packaging, and from off-spec manufactured material.

- Plastic manufacturers (NAICS 325211) are responsible for generating various plastic resins that are then combined and molded into products. This sector is responsible for plastic production; generators reuse the vast majority of their manufacturing byproducts. It is efficient to rework this material back into industrial processes (OECD 2006 p.88). The efficiency stems from the fact that process scrap is typically made up of single-type plastic. However, even scrap from multi-layer food packaging can be reworked into the original process provided that food contamination is limited (Robertson 2005, p.26).
- Data on the generation of scrap plastics are not readily available, but the largest market for the use of virgin plastic resins is packaging. Packaging (NAICS 32611) accounted for 33 percent of plastic industry sales in 2007 (ACC 2008a).
- The second largest industrial market for virgin plastic, at 21 percent, is the manufacture of consumer products (NAICS 31-33) (ACC 2008a).
- The third and final substantial industry using plastic is building and construction (NAICS code 23), with 17 percent of the market (ACC 2008a). PVC in particular is used primarily in plastic pipes (NAICS 32612) (Ernes & Griffin, 1996, p.180).

(2) **Quantities of Scrap Plastics Generated:** The Plastics Industry Producers' Statistics Group reports that the plastics industry in North America produced approximately 46.4 million tons of thermoplastics in 2007. Polypropylene makes up the largest share of virgin plastic production at approximately 9.7 million tons. PVC is the only halogenated plastic with substantial production in 2007, with 7.3 million tons (ACC 2008c). Data from the Netherlands suggest that the plastic processing industry is approximately 95 percent efficient, as measured by the ratio of plastic scrap generated to plastic material input (Joosten, et al, 2000, p.154). Assuming U.S. plastic processors are similarly efficient, the volume of plastic scrap generated would be

approximately 2.4 million tons. Exhibit 1 lists the annual quantities of virgin plastic generated in 2007 for each type of plastic.

Data are not available on specific users and volumes of plastic scrap. One source suggests, however, that 75 to 90 percent of plastic scrap from production of plastic products in the United States in the early 1990s was recycled due to the efficiency with which manufacturers can reuse single polymer uncontaminated scrap in their production processes (OECD 2006 p.88). A representative of Holcim Group Support Ltd. reports that some scrap plastic – typically off-spec products – is obtained through direct agreements between specific producers and cement kilns for fuel, but sources and quantities of plastics used are considered competitive information throughout the industry (Guerra 2008). In addition, the combustor survey database developed by EPA for the 2009 proposal of the Commercial and Industrial Solid Waste Incinerator (CISWI) standards and the Industrial Boilers Maximum Achievable Control Technology (MACT) standards indicates that the sources surveyed for these rules annually combust 39,000 tons of material characterized as plastics.[1]

Exhibit 1: Overview of Plastic Production in North America for 2007

Plastic Type	**Annual Quantity Generated (tons)**
Low-density polyethylene (LDPE)	4.0 million
Linear low-density polyethylene (LLDPE)	6.8 million
High-density polyethylene (HDPE)	9.1 million
Polypropylene (PP)	9.7 million
Acrylonitrile butadiene styrene (ABS)	0.6 million
Other Styrenics	0.9 million
Polystyrene (PS)	3.0 million
Nylon	0.7 million
Polyvinyl chloride (PVC)	7.3 million
Thermoplastic Polyester (includes PET)	4.4 million
Total Thermoplastics	**46 million**
Source: ACC Plastics Industry Producers Statistics Group, as compiled by Veris Consulting, LLC	

[1] Although we report plastics from the combustion database as tonnages, the database includes material quantities expressed in terms of heating values (Btu). To express this information as a tonnage, we assumed that plastic has a heating value of 13,625 Btu per pound, which is the midpoint of the 8,250 to 19,000 Btu/lb range for plastics reported by the Energy Information Administration (EIA 2008). Also, for the purposes of identifying materials as plastics in the combustion database, we assumed that the following materials are plastics: (1) ground toilet seats, (2) packaging trimmings, and (3) plastics.

(3) **Trends in Generation:**

- Plastic generation has remained constant over the last several years. Measured by weight, production of plastic grew 2.6 percent from 2003 to 2007, as shown in Exhibit 2 (ACC 2008e). This is likely a reasonable indicator of trends in production of scrap plastic.

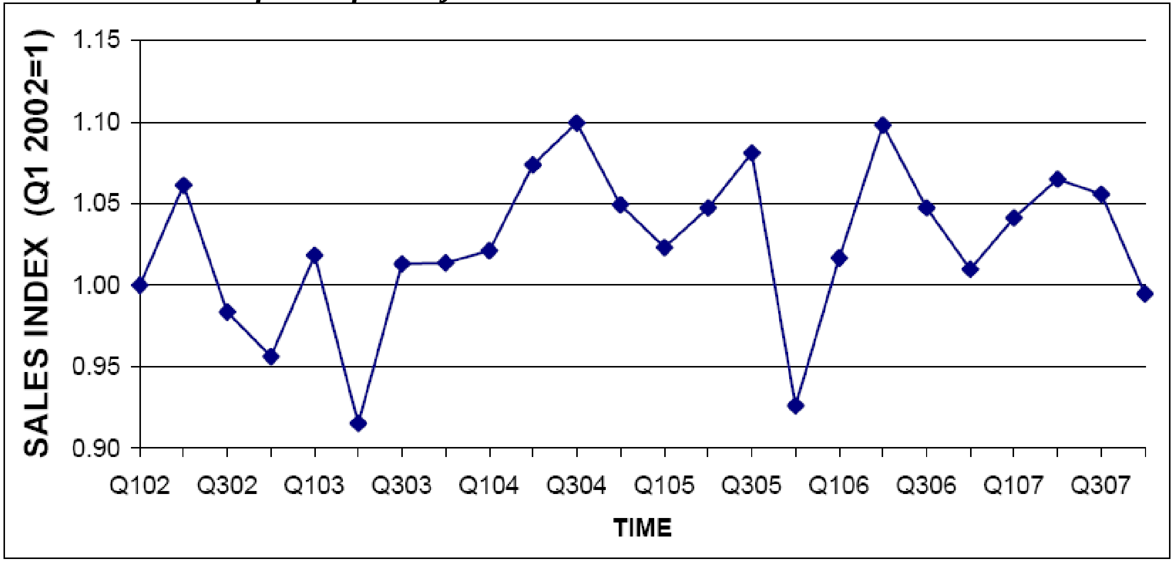
Exhibit 2: Summary of Plastic Markets from 2003 to 2007

Sector	Tons of Plastic Used				
	2003	**2004**	**2005**	**2006**	**2007**
Transportation	2.4 million	2.4 million	2.4 million	2.3 million	1.7 million
Packaging	12 million	13 million	13 million	13 million	13 million
Building & Construction	7.2 million	7.8 million	7.7 million	7.7 million	7.1 million
Electrical/Electronic	1.4 million	1.5 million	1.5 million	1.3 million	1.0 million
Furniture & Furnishings	1.7 million	1.7 million	1.7 million	1.7 million	1.5 million
Consumer & Institutional	8.8 million	9.4 million	8.7 million	8.9 million	8.6 million
Industrial/Machinery	0.5 million	0.5 million	0.5 million	0.5 million	0.5 million
Adhesives/Inks/Coatings	0.6 million	0.6 million	0.6 million	0.6 million	0.5 million
All Other	1.0 million	1.1 million	1.1 million	1.0 million	0.8 million
Exports	4.5 million	5.0 million	4.9 million	5.0 million	6.2 million
Total Selected Plastics:	**40 million**	**43 million**	**42 million**	**42 million**	**41 million**

Source:
ACC Plastics Industry Producers Statistics Group, as compiled by Veris Consulting, LLC
Note:
Selected plastics include LDPE, LLDPE, HDPE, PP, Nylon, PVC, Engineering Resins, PS, ABS, Styrene-Acrylonitrile (SAN), Other Styrene-Based Polymers, and Styrene Butadiene Latexes. Data from 2007 do not include ABS, SAN, Other Styrene-Based Polymers, and Engineering Resins.

- An index from the same source reports sales and intra-company use of major plastic resins in the fourth quarter of 2007 were slightly lower than the first quarter of 2002, with a peak of 10 percent higher than 2002 in the third quarter of 2004 and a trough of 8 percent lower in the second quarter of 2003 (ACC 2008f). See Exhibit 3 below.

Exhibit 3: Trend of Sales for Major Plastic Resins



Source: ACC Plastics Industry Producers Statistics Group, as compiled by Veris Consulting, LLC

3. Uses of Scrap Plastics

(1) **Fuel Uses:** Combustion of post-industrial scrap plastic for energy in the United States does not appear to represent a high volume alternative fuel option. Data suggest that the same characteristics that increase the value of plastic scrap as an alternative fuel (e.g., high energy value) also increase its value as an input to recycled products, because it avoids the expense and raw material costs associated with virgin plastic. Anecdotally, however, several examples of cement kilns, boilers, and other incinerators using plastic as a fuel source exist:

- A cement kiln in Westport, New Zealand, experimented with sourcing scrap from plastic manufacturers in 2006 (Plastics New Zealand 2006, p.1).
- A consultant with expertise in environmental regulatory compliance reports that plastic scrap from pharmaceutical packaging and diaper manufacturing scrap have been or are considered usable in cement kilns (Gossman 2007).
- A Holcim representative reports that the company uses off-spec plastic products in its cement kilns (Guerra 2008). The company also in some cases obtains plastics from recyclers who handle MSW and commercial waste.
- Dynegy Midwest Generation was reported to burn more than 500 tons of polyurethane scrap and other materials per day in engineered fuels to generate electricity. According to Dynegy's estimates, for each ton of coal displaced by polyurethane scrap, there is a reduction of more than eight pounds of SO2 emissions. (Center for the Polyurethanes Industry 2007.)
- KeLa Energy, LLC, has a patent pending binding process to create synthetic coal-based engineered fuels using readily available waste plastics and plastic composites, including post consumer carpet, to bind waste coal fines. Biomass may also be included in the binder system. The KeLa synfuel produces lower SO_2 and NOx emissions than does coal. The engineered fuel has been tested in

industrial boilers and work is ongoing to allow its use in utility boilers. (KeLa Energy press release, 2007).

Because it is a refined hydrocarbon material, plastic scrap is a high-value alternative energy source. However, plastics from some sources may be contaminated in ways that limit their value as fuel. For example, mixed plastics may include PVC, and the presence of significant levels of heavy metals (e.g., e-waste) make certain types of plastic scrap unfavorable for use as a fuel.

(2) **Non-Fuel Scrap Plastic Uses:** The vast majority of scrap plastic is mixed with virgin plastic of the same type and reused in the same or a similar manufacturing process. This process is called "regrinding." Numerous other products are made from "downcycled plastic." The American Chemistry Council reports (ACC 2008d):

- Recycled PET can be used in new food and beverage bottles (i.e., "closed loop" recycling) and "downcycled" into deli trays, carpets, clothing, and automobile parts.
- Recycled HDPE can become bottles for laundry products and motor oil, recycling bins, agricultural pipe, bags, garden edging, decking and plastic lumber.
- Recycled vinyl can become playground equipment, flooring tiles, film, and air bubble cushioning.
- Recycled LDPE can be used to manufacture bags, compost bins, and plastic lumber.
- Recycled PP can be used in automobile parts including battery casings, textiles, industrial fibers, and films used for bulk packaging.
- Recycled PS can be used in products including office accessories, garden nursery supplies, and protective package cushioning.

(3) **Quantities of Scrap Plastics Landfilled:** Due to the efficiency with which post-industrial plastic scrap can be recycled and the robust market for plastic scrap, it does not appear that significant volumes of post-industrial plastic scrap end up in landfills. An exception may be off-spec products with multiple materials, although data are not readily available to quantify this.

(4) **Quantities of Scrap Plastics Stockpiled/stored:** Data are not readily available on the stockpiling or storage of plastic scrap, but because there is no restriction on disposal, it is likely that most discarded plastic is disposed of in municipal or other non-hazardous landfills. It is possible that private stockpiles of plastic exist, but given the high market prices for scrap plastics at this time it is not likely to be a widespread practice.

4. Management and Combustion Processes for Scrap Plastics

(1) **Types of Units Using Plastic Scrap as a Fuel:** As explained above, combustion of post-industrial scrap plastic appears to be common in the cement industry. We are unable to find evidence of wide-spread combustion of post-industrial scrap plastic in

the United States by other industrial furnaces or boilers, beyond the examples noted above.

(2) **Supply/Processing Chain for Plastic Scrap**: As described earlier, a significant portion of plastic scrap is reworked into the production process (i.e., recycled internally). In this case, no transportation is necessary. Off-spec materials used as fuel appear to be transferred directly from the producer to the combustion unit or fuel blender, where they are typically ground or shredded prior to combustion. For post-consumer (MSW) plastic, the process is somewhat different. Material is collected and sorted by municipal recycling facilities (MRFs) or private sector recycling operations into different common types of plastic such as PET and HDPE, and in many cases some decontamination also takes place prior to baling the product to sell as scrap.

(3) **Processing Scrap Plastic for Fuel Applications:**
In a mass burn furnace, plastic scrap could be combusted with no further processing. In an refuse-derived fuel (RDF) facility and in most cement kilns and boilers, scrap is shredded prior to combustion and mixed with other fuel sources to provide a consistent fuel stream. Because industrial scrap plastic is typically uncontaminated and of a single type, it is unlikely that facilities with industrial boilers or kilns would need to clean the plastic prior to combustion.

(4) **Changes to Increase Use in Combustion:** Post-industrial plastic scrap is already well-suited to combustion due to the high energy content and uncontaminated nature of most of this material. From the limited data available, it appears that use of post-industrial plastic scrap as fuel is not more widespread due to competing uses as an input into new plastic product manufacturing.

(5) **State status of Scrap Plastic use as Fuel:**
At this stage we have not identified any states that have approved use of scrap plastics as fuel, but we have not performed an exhaustive investigation of state activities and regulations.

5. Scrap Plastic Composition and Impacts

(1) **Composition of Scrap Plastic**
Scrap plastic has a high energy content ranging from 8,250 to 19,000 Btu per pound (EIA 2008). This can compare favorably with coal at 10,300 Btu/pound (EPA 2008a). Non-halogenated plastics are composed primarily of hydrocarbons with the addition of a wide variety of possible additives (ACC 2008b). PVC contains a substantial amount of chlorine.

Exhibit 4: Heating Value for Common Plastics

Plastic Type	Btu/Lb.
PP	19,000
PS	17,800
LDPE/LLDPE	12,050
PET	10,250
Other	10,250
HDPE	9,500
PVC	8,250

Source:
EIA 2008

(2) **Impact Information**

- ***Greenhouse Gas Emissions:*** The greenhouse gas emissions from combustion of plastics vary by type of plastic. Combustion of HDPE produces the highest GHG emissions with 0.149 MTCO2E per MMBtu, while PP produces the lowest at 0.072 MTCO2E per MMBtu. Generally, plastics appear to have higher greenhouse gas emissions than primary fuel sources. The emission factors associated with several common types of plastic are listed in Exhibit 5. By comparison, based on emissions and energy data compiled by EPA, the GHG emissions rates for coal, natural gas, distillate oil, and residual oil are approximately 0.094 MTCO2E per MMBtu, 0.053 MTCO2E per MMBtu, 0.073 MTCO2E per MMBtu, and 0.079 respectively (EPA 2008b, Table A-10).
- ***Criteria Pollutants and Hazardous Air Pollutants:*** Although several studies have been conducted on the criteria pollutant and hazardous air pollutant (HAP) emissions associated with combustion of plastics, most of these studies examine fuels that are a combination of plastics and other materials, especially MSW. Therefore, these studies do not isolate the criteria pollutant or HAP emissions associated with scrap plastics alone. Nonetheless, uncontaminated scrap plastics tend to be purified petrochemicals and potentially emit lower levels of pollutants than combustion of other fossil fuels.
- ***Additional Avoided Impacts:*** In addition to other air emissions associated directly with combustion, use of scrap plastics as a replacement for traditional primary fuels may eliminate the environmental impacts associated with extraction and processing of the traditional fuels. Note that this assumes that the scrap plastic used as fuel is not economically recyclable. Exhibit 6 lists the quantities of cradle-to-gate emissions for these fuels based on typical processes in the United States in the late 1990s.

Exhibit 6: Emissions from Extraction and Processing of Traditional Fuels

Pollutant	Coal	Distillate Fuel Oil	Residual Fuel Oil	Wood	Natural Gas
	-------------------- *Lb./MMBtu* -----------------				
Criteria Pollutants					
PM2.5	-	-	-	-	-
PM10	-	-	-	-	-
PM, unspecified	0.246	0.012	0.012	6.67×10^{-4}	0.004
NOx	0.022	0.061	0.062	0.08	0.117
VOCs	0.008	0.361	0.365	-	0.515
SOx	0.022	0.186	0.187	0.003	1.913
CO	0.017	0.046	0.046	0.022	0.223
Pb	2.60×10^{-7}	1.01×10^{-6}	1.00×10^{-6}	-	2.72×10^{-7}
Hg	8.17×10^{-8}	1.87×10^{-7}	1.87×10^{-7}	-	7.18×10^{-8}
Greenhouse Gases					
CO_2	3.9	19	19.1	-	15.3
CH_4	0.451	0.029	0.029	-	0.369
N_2O	1.63×10^{-5}	2.01×10^{-5}	2.07×10^{-5}	-	1.17×10^{-5}
MTCO$_2$E/MMBtu	**0.006**	**0.009**	**0.009**	**-**	**0.01**

Source:
Franklin Associates 1998
Note:
"-" signifies data not available; may equal zero.

The emission information presented in this table is derived from Life Cycle Inventory (LCI) data, as compiled by Franklin Associates. LCI data identifies and quantifies resource inputs, energy requirements, and releases to the air, water, and land for each step in the manufacture of a product or process, from the extraction of the raw materials to ultimate disposal. The LCI can be used to identify those system components or life cycle steps that are the main contributors to environmental burdens such as energy use, solid waste, and atmospheric and waterborne emissions. Uncertainty in an LCI is due to the cumulative effects of input uncertainties and data variability.

There are several life cycle inventory databases available in the U.S. and Europe. For this paper, we applied the most readily available LCI database that was most consistent with the materials and uses examined. These LCI data rely on system boundaries as defined by Franklin Associates, as described in the documentation for this database, available at: http://www.pre.nl/download/manuals/DatabaseManualFranklinUS98.pdf.

- ***Cost Impacts:*** A Holcim Group Ltd. representative reports that in most or all cases, Holcim is paid by manufacturers to take their plastic scrap. This arrangement often represents a cost savings to generators due to avoided disposal, although in some cases manufacturers are willing to pay a premium over other options to see their plastic scrap used for productive purposes (Guerra 2008).

Finally, note that, while scrap plastic represents a high-quality fuel source, at this time post-industrial scrap plastic appears to be more valuable as recycled products. As energy prices rise, making plastic a more attractive fuel source, the prices of virgin plastic also rise, resulting in increased emphasis on recycling. However, for plastics that are difficult or impossible to recycle economically, combustion of scrap plastic, particularly by cement kilns, is increasingly attractive both as a cost savings opportunity for companies, and also as an opportunity to ensure that they are optimizing their materials management strategies to recover the value of their materials.

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